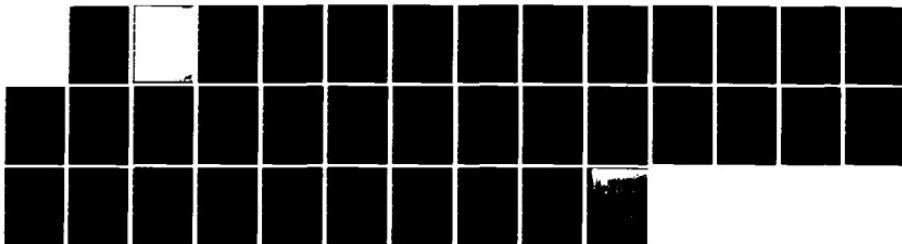
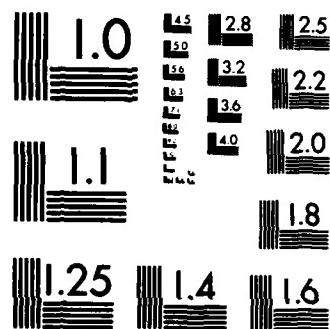


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USAWC MILITARY STUDIES PROGRAM

FUTURE ENERGY AND UNITED STATES SECURITY

INDIVIDUAL ESSAY

by

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Carlisle Barracks, Pennsylvania 17013
13 April 1983

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ABSTRACT

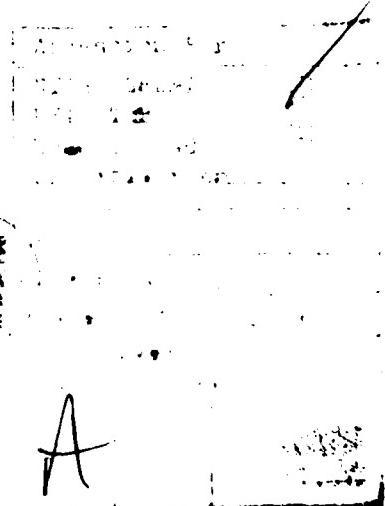
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→ Coal, nuclear energy, synthetic fuels, renewable energy sources, and conservation were examined as alternative energy sources to petroleum for the United States. These sources offer feasible alternatives for petroleum and will allow for the maintenance of US security. The US can and must enter a multipronged, four phased program designed to reduce oil imports to zero by 1990 and progress toward solar and biomass as primary sources of energy by the year 2000. Technology and domestic energy sources exists for the US and her allies to become energy independent.



FUTURE ENERGY AND UNITED STATES SECURITY

The purpose of this paper is to discuss the current United States energy situation, examine alternative energy sources for petroleum and then present an energy strategy necessary for the United States to preserve its national security. For purposes of this paper national security involves far more than our country's war-fighting capability. It includes our ability to deter an attack, the military strength of our allies, our relationships with those allies, their ability to deter attacks, the flexibility of our foreign policy, the economic viability of our allies and our own economic strength.¹

Energy consumption in the United States currently amounts to the equivalent of 35 million barrels of oil per day, accounted for by oil (43 percent), natural gas (27 percent), coal (22 percent) and nuclear, hydro-power and other forms of energy (8 percent).²

In 1981, the United States produced 88 percent of the energy it consumed, the highest level of domestic energy reliance in a decade. The remaining 12 percent was imported, mainly as oil--an import level significantly below the peak in 1977 when the US imported 24 percent of its energy needs. This decline in imports is the result of both a large drop in domestic energy consumption and an increase in domestic production. Net oil imports are currently averaging 4.1 million barrels per day.³

Since the embargo of 1973, we have seen a change in the mix of fuels contributing to energy growth. Previously growth came from oil and natural gas; while since 1973, virtually all of the energy growth has come from coal and nuclear power.⁴

In order to continue to reduce our energy consumption, it is important that we understand how our energy is used. Nationwide, on the average, we use about 36 percent of our energy for industry, 26 percent for transportation, and 19 percent each for residential and commercial applications. It is instructive to note that about 15 percent of our total energy consumption is reflected in gasoline demand for automobiles. In the overall sense over 50 percent of our total petroleum consumption occurs in the general transportation market.⁵ A solution to our transportation problem will contribute significantly to decrease our reliance on petroleum. Technology, which will be discussed later, does exist which will allow for the production of more efficient vehicles significantly reducing our reliance on petroleum and for the production of motor fuel from coal and biomass.

Our energy problem is not one of absolute shortage. There is an abundance of energy. Considering only petroleum as an energy source, conservative estimates maintain that Saudi Arabia and Kuwait have reserve-to-production ratios of fifty to seventy-five years. Domestic alternative energy sources can be developed well within that time.⁶

Supplies of future energy lie in the following sources:

A. Oil and Natural Gas: While the primary purpose of this paper is to discuss alternatives to petroleum, petroleum must be discussed as it is important as an interim energy source in any program designed to wean the United States from petroleum. Some analysts believe that more oil and natural gas will be found and produced in America in future years than in all of the past. This country is a long way from exhausting its potential supplies of these two fuels.⁷

Six basic facts about oil and gas will be addressed:

1. More Domestic Oil and Gas Can Be Found and Produced. This country can continue finding and producing oil and gas by:

- o exploring onshore and offshore frontier areas which have never been tested with the drill;
- o drilling deeper in areas which are already productive;
- o re-examining older, mature producing areas in such states as Pennsylvania, New York, Ohio and West Virginia;
- o Using more sophisticated technology to find petroleum; and
- o applying the most efficient recovery methods available to cook as much oil and gas as possible out of the earth. There are 300 billion barrels of known oil resources in the United States which until now have been uneconomic to produce. If even 10 percent of that oil can be produced through enhanced recovery methods now being developed, todays proven oil reserves would double.⁸

This country's total potentially recoverable oil and natural gas resources can be conservatively estimated as:

- o 137 billion barrels of crude oil and 27 billion barrels of natural gas liquids; and
- o 950 trillion cubic feet of natural gas (the energy equivalent of 167 billion barrels of oil).

To put those figures into perspective, that would be:

- o more than 40 times the petroleum and natural gas liquids and about 50 times the natural gas produced in this country in 1980; and

o more oil and gas than this country has produced in the history of the petroleum industry. Cumulative production from 1859 through 1980 included about 143 billion barrels of oil and natural gas liquids and about 600 trillion cubic feet of natural gas.⁹

2. Major Future Discovery Areas Are the Western States, Alaska and Offshore. The vast majority of the untested areas believed to have oil and gas potential are controlled by the federal government, which has not made the great bulk of those lands available for exploration and drilling. Studies by the United States Geological Survey concur with analyses by industry and academic specialists that the nation's chances of finding major new oil and gas fields increase if leases are made available in these relatively untested areas. The USGS estimated in 1981 that offshore areas out to a water depth of 2,500 meters many contain 34 percent of the undiscovered oil and 28 percent of the undiscovered natural gas in the nation.¹⁰

3. Government Controls Access to Promising Areas. Only 15 percent of the federally owned onshore lands--109 million out of 738 million acres--were leased for oil and gas operations as 1981 began. In 1980, wells on those leases provided more than 4 percent of the crude oil and natural gas liquids and more than 5 percent of the natural gas produced in this country. These percentages can be increased significantly during the 1980s through greater access to those lands.¹¹

The federal government controls 528 million acres of submerged lands on the Outer Continental Shelf--the area between the edge of state jurisdiction and the 200 meter water depth. The government also controls nearly 438 million additional acres in deeper water, to a depth of 2,500 meters. From the beginning of federal offshore leasing in the 1950s through 1980, only 19 million of the 528 million OCS acres were leased--less than 4

percent of the total. Many of the older leases have expired. At the end of 1980 only 10.7 million federal OCS acres--2 percent of the total--were under lease for petroleum operations. Yet, during 1980, those federal leases accounted for about 9 percent of the crude oil and condensate and 23 percent of the marketed natural gas produced in the nation.¹²

4. Government Affects Petroleum Development Through Environmental Laws and Regulations. The federal government has adopted a series of major environmental laws in response to public concern about environmental pollution. These laws have brought about a substantial improvement in the nation's air and water over the past 10 years. The vigorous pursuit of environmental goals, however, has limited the development of this country's resources, including domestic oil and gas. It has also led to increased dependence on imported oil. Existing constraints on energy development can be reviewed by Congress and remedial action can be taken to help the nation develop its energy resources while still protecting the environment.¹³

5. Decontrol and Higher Prices Increase Investment in Exploration and Production. The removal of federal controls on crude oil and higher prices allowed for some categories of natural gas are making it possible for US petroleum companies to increase their investments in exploration and production.¹⁴

6. Oil Companies Are Working to Find More Petroleum. The nation's oil companies are reaching vigorously for the oil and gas supplies this country needs. They have the technology and the skilled personnel to operate with a high degree of efficiency. From Alaska to the Gulf of Mexico they have proved that petroleum operations can be carried on in harmony with the nations environmental goals.

Improved prices for domestic producers are helping the oil companies to:

- o speed up the search for new oil and gas fields;
- o go after oil and gas which would not have been produced economically under the old federal price ceilings;
- o Use advanced technology to increase oil recovery from existing fields; and
- o keep many older wells active longer.

Although exploratory drilling will be extremely important in maintaining petroleum production, much of the oil this country will need in coming years does not have to be discovered. Existing fields contain an estimated 300 billion barrels of oil which until recently have been economically unproductible. Conventional production methods, on average, have recovered from the ground only about one-third of all the oil ever discovered in this country. With adequate incentives and continued technological advances, most estimates indicate that future production of oil in the United States could be increased by around 30 billion barrels with the use of newer techniques. That would represent a doubling of current proved reserves.¹⁵

B. Coal: Coal is the most abundant fossil fuel in the United States, accounting for more than three-fourths of known recoverable energy reserves. And the United States has more than one-half of the free world's coal resources.¹⁶ The United States has about 250 billion tons of coal containing more than double the energy of the Middle East's problem oil reserves, which could be mined with equipment available today.¹⁷

Technology already exists, and is in use, to mine and burn coal in an environmentally acceptable way. Furthermore, coal can be changed to clean burning liquid and gaseous fuels that can directly replace petroleum. The

nation can expand the use of coal while continuing to improve the quality of the environment.¹⁸

Abundant and reasonably priced supplies of coal can help boost productivity across the nation's economy. First, if the nation chooses to accelerate the development of its coal reserves, American industries will have greater access to more reliable and less expensive energy supplied by coal. Second, since coal costs less than fuel oil, electricity generated by coal is helping to hold down the cost of electricity to homeowners and other consumers. Finally, money paid for coal stays in the United States and, thus, helps to improve the nation's balance of payments.¹⁷

Government and industry leaders alike agree that coal can make a much greater contribution to the nation's future energy needs in an environmentally acceptable way. Even environmental officials in the Carter administration have said that environmental problems associated with the burning of coal in large quantities are not insurmountable. In March 1980, the Presidents Commission on coal, after a two-year study, concluded that, "the problems associated with coal use can be overcome, and that this nation must begin to rely more heavily on its vast coal deposits to reduce much of our intolerable dependence on imported oil."²⁰

Many different new processes and techniques are being demonstrated in pilot plants or are undergoing testing in research facilities. These processes and techniques can be grouped into four categories:²¹

- a. Coal cleaning processes--which remove most of the impurities from coal before it is burned;
- b. Emissions control devices--more sophisticated equipment which removes pollutants during the process of coal combustion;
- c. New coal technologies--which, when developed, will use coal efficiently and without environmental hazards; and

d. Synthetic fuels from coal--the conversion of coal to a liquid or gaseous form. The conversion process removes the potential pollutant and produces a fuel which can be used in the combustion equipment already in place.

Gasification and liquefaction is attractive because a convenient infrastructure already exists to transport oil or gas. It will burn in our current engines and power plants. Moreover, energy in either of these two forms is cleaner than can be had by the direct combustion of coal, because the technology to curb pollution from burning oil and gas is more developed and less expensive.²²

Liquefaction in particular is one weapon against increasing dependence on foreign oil. It is being used for precisely that purpose by another country with plentiful coal reserves, the Republic of South Africa. South Africa has an extensive liquefaction capability. One facility is already operating, and another much larger liquefaction plant will be on line in the early eighties. At that point, oil-from-coal will account for about 35 to 50 percent of South Africa's total petroleum consumption.²³

In August 1980, a National Coal Association survey found that some 41 coal liquefaction and gasification facilities were operating in the United States. Six others were being built and 42 more were in the planning stage. Many of these were pilot or demonstration plants. The 1981 federal budget involved some of these projects, but others are entirely commercial ventures--a sign that synfuels are no longer strictly experimental.²⁴

C. Nuclear Energy: Nuclear energy has a substantial role to play in the overall energy picture because the United States has been shifting toward reliance upon electrical power. Only about 11 percent of the nation's electrical power is now being generated with nuclear fuel, so there is considerable room for growth.²⁵

Not all signals are positive for the future of nuclear power. Obstacles to nuclear energy development are:

- (1) Availability of enrichment services
- (2) Waste disposal
- (3) Lengthy licensing procedures
- (4) Safety

Nuclear power has proved to be a safe, economical, and environmentally acceptable energy source. Furthermore, the United States has substantial domestic resources of uranium ore, capable of lasting well into the 21st century as used in the current generation of reactors. Breeder technology multiplies the effectiveness of these resources sixty fold, so that they could last easily for several centuries.²⁶

The disposal of waste is frequently referred to as an "unsolved" problem, but nuclear specialists feel that this description is misleading. "All this means," according to Bernard L. Cohen of the University of Pittsburgh, "is that a method of disposal has not yet been decided upon." Indeed Dr. Cohen asserts that nuclear wastes are less dangerous than wastes from burning coal. The technology for the safe disposal of nuclear waste material, as well as the safe storage of spent fuel which could be reprocessed and used again, has been available for some years.²⁷

Permission to construct a nuclear power plant must be obtained from some twelve agencies. An applicant must obtain a construction permit to start work on a power plant and, about two to three years before the plant is to be completed, must apply for an operating license. Once the plant is close to completion, from five to six years later, the company and government agencies must repeat the process in order to issue an operating permit. Frequently this process takes as long as seven months.²⁸

The nuclear industry has an impressive safety record, paradoxically brought to public attention during the national reaction to Three Mile Island. In more than two decades no injury to the public has occurred, and no plant employee has been seriously injured by exposure to radiation.²⁹

The accident at the Three Mile Island Reactor site near Harrisburg, Pennsylvania, in 1979 indicates a need for much closer federal regulation of and attention to plant design, construction, and operation, as well as operator qualification and training. Public opinion, informed or not, may effectively stop nuclear power development if firm and very obvious corrective measures are not taken by the government.³⁰

There are reasons to believe that nuclear energy is ready to resume its growth. As the Atomic Industrial Forum pointed out in 1980, there appears to be this growth consensus about nuclear power: "We can do it better, but we cannot do without it."³¹ With a climate of public acceptance, spent fuel storage and licensing problems, nuclear power can make a significant contribution toward the US energy solution.

D. Synthetic Fuels and Renewable Energy. These new sources include oil and gas made from coal; oil from shale and tar sands; energy derived from the sun's heat (solar thermal) or from sunlight (photovoltaic); fuels from plant matter (biomass); and electric generation from natural forces such as water, wind and the earth's heat (geothermal energy). Hydropower currently provides the longest supply of electricity from natural forces although the growth potential of hydropower is less than that of other natural energy sources.³²

Coal and oil shale are the principal sources of synthetic fuels. Existing processes can extract hydrocarbon resources and/or transform them into synthetic substitutes for conventional oil and gas; and improved processes are being developed. The United States has recoverable coal

resources of around 250 billion tons and recoverable shale oil reserves of about 600 billion barrels. Together these resources amount to more than five times our total recoverable reserves of conventional oil and gas.³³

The idea of producing oil from shale rock is not new. Shale oil production preceded crude oil production in the United States by several years. In the 1850s, some 53 domestic firms manufactured oil from eastern deposits of shale. Shale is a fine-grained sedimentary rock that contains a solid substance called "kerogen," which is partially formed oil.³⁴

The United States is singularly blessed with shale oil deposits. These include the Colorado, Wyoming, and Utah deposits in the Green River Formation, and the Upper Mississippi Valley to Michigan deposits in the Devonian and Mississippian formation.³⁵

Today the USSR produces about 1.5 percent of its total energy requirement from shale. After many years of experimentation in this country, including projects undertaken by the Bureau of Mines during World War II, the Paraho Project was initiated in 1974 by a large consortium of major oil companies on government-leased land in the Piceance Creek Basin at Anvil Points near Rifle, Colorado. The Paraho process fully demonstrated that oil could be extracted from shale in large quantities. Over 10,000 barrels of oil produced from this process were refined and satisfactorily tested by the military for a variety of mobility fuels.³⁶

Always in search of secure and independent sources of fuel, the military has backed the development of shale oil. The Department of Defense (DOD) has been involved in shale oil production since World War I when the government established a Naval Oil Shale Reserve near Rifle, Colorado. Over the past five years, DOD has tested refined shale oil products as both aviation and ground transportation fuel. Thus, shale oil could play an

important role not only as a commercial fuel but also as part of a military fuel reserve.³⁷

From the standpoint of national security, the synthetic fuels program offers two major benefits. First, if the United States demonstrates that it can produce as much as 500,000 barrels a day of synthetic fuel, it will hold in hand one more card that could help moderate price increases. This is especially true in the event that oil demand rises again in response to temporarily stagnating oil prices. The oil-exporting countries could be reluctant suddenly to push prices too high, because the higher the price of oil goes, the more rapidly synthetic fuels would become competitive with oil and more quickly synfuels capacity could be expanded. Ironically a successful synthetic fuels program, one that could moderate price increases, could slow down the commercialization of synthetic fuels.³⁸

The second benefit of the synthetic fuels program would accrue if oil prices were suddenly to accelerate because of some unpredictable political disruption of oil production or exports, for the United States would have in place considerable productive capacity. Under such circumstances a sudden price increase in the world oil market would act as a tripwire accelerating the commercialization of synfuels plants previously subsidized by the US government. Thus, the synthetic fuels program could provide significant economic benefits under both turbulent and relatively calm market conditions.³⁹

Tar sands are sands found in their natural state saturated with heavy oil or tar. The United States has considerable tar sands deposits--enough to equal twice our proved crude oil reserves--but most of them are difficult to extract. Canada has much greater deposits of tar sands that can be recovered by the easier, less expensive, surface mining method and commercial production is already underway.⁴⁰

In the United States several factors have inhibited the development of tar sands reserves. First, the United States has much smaller reserves than Canada, and only a small portion of US reserves are recoverable by the surface mining method. Second, the US surface-minable deposits are a different type of tar sands than Canada's, and separation of the oil from the sands would require a different process. Third, the surface mining process faces environmental and land-leasing problems. Finally, the process requires substantial amounts of water--a limited resource much in demand in the Utah deserts where most US deposits lie. Thus, production of oil from tar sands in the United States is not expected to be significant during the next ten years.⁴¹

Decontrol of conventional fuel prices, revitalization of the economy, and removal of regulatory uncertainties will improve the growth climate for synthetic fuels.⁴²

Biomass is not only one of the oldest but also one of the most accessible sources of energy. Biomass includes every kind of organic substance that can be turned into fuel. Wood and dry plant or organic waste can be burned directly to generate heat and electricity. All organic matter can be converted into alcohol. Bacteria can break down organic wastes into methane. Biomass conversion has unique advantages over most other energy technologies. First, the resources are renewable, unlike coal or petroleum. Second, conversion of municipal and industrial wastes into useful fuels can help solve two of the nations problems simultaneously. It can both increase energy supplies and help clean up the environment.⁴³

At present, perhaps the most important biomass fuel is alcohol. A variety of alcohols--including ethanol and methanol--can be produced from plant and animal matter. Currently, distillers in the United States process ethanol from cornstarch, local waste, cheese whey, wheat and wood

wastes. These liquids can supplement petroleum both as industrial feedstocks and as motor fuel.⁴⁴

Most manufacturers use ethanol derived from petroleum to make chemicals, solvents, detergents and cosmetics. However, before the growth of the petrochemical industry in the 1940s, manufacturers used ethanol made from biomass. As the price of crude oil rises, biomass-based alcohols once again are competing with ethanol made from petroleum. Twenty percent of the alcohol used by industries is made from biomass.⁴⁵

The use of alcohol as a motor fuel dates back to the 1880s when some of the first automobiles ran entirely on alcohol. During the 1920s, farmers began to mix alcohol with gasoline. Gasohol--a blend of 90 percent gasoline and 10 percent ethanol--originally was called agrifuel, agrol or alky-gas.⁴⁶

Alcohol is regarded as a significant supplement to gasoline for two reasons. First, efficiently produced alcohol can stretch supplies of motor fuel. Second, alcohol raises the octane rating and thus, can help refiners produce high-octane unleaded motor fuel. The Energy Security Act, passed in June 1980, set a goal for production of 60,000 barrels of alcohol a day by the end of 1982.⁴⁷

Presently the economics of biomass energy are tenuous, given the relatively low cost of conventional fuels. But this will change. A current example of cost effective farming would be growing grain to produce alcohol, which would leave a residue of high-protein cattle feed. The cattle produce food for human consumption; their waste produces energy, if converted to methane, which in turn produces processed heat to run the alcohol distillery; then the alcohol produced in the first place drives the tractors and machinery of the farm. This kind of organization requires thinking that is both precise and small: thinking incrementally. It is

not what economists are accustomed to doing. Like architects, they like grand solutions, of which--we are persuaded by their efforts to date--there are none. A far more practical alternative than the massive gasohol factories proposed for America's cornbelt is a small community-scaled still, capable of meeting regional energy needs and operating on local crop residues and a portion of local agricultural production. One such plant was put into operation in October, 1980, by the Jones Energy Corporation at Jerome, Idaho. This small plant makes about a half million gallons of alcohol a year. Jones predicts that the \$1.2 million plant is only the forerunner of a whole new generation of efficient alcohol technology on the local level. There really is no need to make anhydrous-grade alcohol (200°) for gasohol production. Producing lower-proof alcohol (160-170°) that can be used directly in cars, trucks and tractors is a better solution. This saves a substantial part of the energy in the production process required to make anhydrous-grade alcohol.⁴⁸

Americans throw away at least 150 million tons of garbage each year. A considerable amount of this solid municipal waste could be converted into energy. However, there are now fewer than 25 trash-to-energy plants in operation in the United States. And less than one percent of the nation's municipal waste is now being used to generate energy. In contrast, Sweden, the Netherlands and Denmark convert 40 percent of their municipal waste into energy.⁴⁹

A February 1979 General Accounting Office study estimates that by 1985 the United States could process 18 percent of the nation's garbage into energy. Municipal solid waste "could provide the nation with annual energy savings equivalent to 48 million barrels of oil." And the federal government can help. As the study also notes,

if technologically and economically viable waste-to-energy systems are to be used on an accelerated schedule in the near-and mid-term, a more active role by the federal government is required.

With the government's help, the nation could add to its energy supply and at the same time help solve the problem of waste disposal.⁵⁰

The oil embargo caused the sun to become a very serious alternative source of energy. The issue has become how much solar energy, what kind--and when. Estimates vary, stating that between 20 and 40 percent of our energy could come from solar energy by the year 2000 if we make some dramatic moves now.⁵¹

New technology is not required to realize solar's potential, for the kind of relatively low level technology needed for a 20 percent contribution is already here, or very close to being here.⁵²

I have chosen to concentrate on three of the most important technologies. The first, solar heating, could have a major impact on US energy consumption in the next ten years. The second, the power tower is the leading recipient of research for the central solar generation of electricity. The third technology, photovoltaics, converts light to electricity using the semiconductor, the basis of the transistor and integrated circuit industry. Each of these three solar options differs in its level of technological advancement, its market potential, and the economic and institutional barriers it faces.⁵³

Solar heating is the most technically mature of all on-site solar technologies. It is hardly a new technology at all, but rather represents a return to a path abandoned only during the last hundred years or so.⁵⁴

Today, a design that manages to take advantage of the sun with few or no moving parts is called passive solar heating. The structure itself is sited and landscaped so that it becomes in effect a large solar collector.

Much experimentation and learning--and relearning--is now occurring with passive solar heating. Enough is already known, however, to argue that incorporation of such design into all structures need not add appreciably, if at all, to building costs, especially as the methods become more familiar.⁵⁵

For most of the next decade, solar heating will make its principal impact in the form of active systems, especially for heating water, which are retrofitted onto existing structures. These are called active systems because they involve mechanical moving parts. Panels about three feet by seven feet are bolted on the roof. Generally made of aluminum, glass, plastic, and copper, the panels catch and concentrate the sun's rays, which in turn heat water, air, or some other medium that flows in pipes through them. Fans or pumps then circulate the medium through a heat exchanger in a water-filled storage tank. The hot water in the storage tank can be used either directly or to heat the house by pumping it through a conventional radiator network.⁵⁶

Many people still assume that solar energy is something for the future, awaiting a technological breakthrough. That assumption represents a general misunderstanding, for active and passive solar heating is a here-and-now alternative to imported oil. The potential for solar heating is vast, because it is well suited to most new residential and commercial buildings and to about one third of the nation's 55 million existing dwellings. By the year 2000, active and passive solar heating could replace 3 million barrels daily of oil equivalent (mbde).⁵⁷

High in the French Pyrenees sits a sparkling ten-story parabolic mirror that looks from an distance like a oversized diamond nestled in a sloping green valley. It is a 1 megawatt solar furnace--a power tower. In 1977 this solar furnace was the only solar thermal electric system in the

world that was pumping power into a conventional electric grid. Although the structure was designed primarily for achieving high temperatures for research purposes, the French tapped off some of the heat to prove a point: that solar energy could be used to generate conventional electric power.⁵⁸

The system works by reflecting the sun's rays onto the large parabolic mirror via an array of smaller mirrors perched on an adjoining hillside. The parabolic mirror focuses the incident light onto a small area where a boiler is placed. The steam produced by the boiler is piped down to a small building that contains a 100 kilowatt steam turbine-generator combination.⁵⁹

The budget for US solar thermal electric program is growing rapidly. Despite criticism of the high costs of the program and skepticism about a centralized "technological fix" that has grown out of the nuclear experience, the solar thermal electric program, better known as the power tower, commands nearly a fifth of the entire federal budget for solar energy. The power tower, the farthest along technologically of several centralized electric generating systems, is expected to continue to command a major share of the federal solar energy funds through the 1980s.⁶⁰

The US power tower is a low-temperature system designed specifically to generate electric power. It is presently at the prototype stage. Eighty percent of the cost of the early stages will be borne by the federal government; later, the participating utilities will increase their share to fifty percent. The first commercial station, a 100 megawatt system, is projected for the early 1990s.⁶¹

The logic of photovoltaic conversion is very persuasive. Silicon, the principal raw material used in the manufacture of photovoltaic cells, is the most abundant solid element on earth. And photovoltaic cells alone

convert sunlight into one of the most highly prized energy forms--electricity.⁶²

Although the cost of photovoltaic cells has been dropping dramatically, they are still very expensive to manufacture. The continued reduction of costs could open up a vast market of conventional electric power generation via photovoltaics. At the heart of the cost reduction problem is the high cost of single crystal silicon.⁶³

There is a wide consensus that in order to penetrate the broader market, the industry must move away from single crystal silicon. A reduction in cost to a tenth of present levels is necessary to make photovoltaics competitive with conventional fuels. And reaching these cost levels will probably require a radical move to very thin cells, up to 100 times thinner than the thickness of today's cells or to amorphous semiconductors--or both. Researchers at RCA and at Energy Conversion Devices have already demonstrated cells with feasibility of thin-film amorphous cells with moderate efficiencies. Stanford Ovshinsky, the inventor of the thin-film semiconductor, estimates that in a few years electricity generated by amorphous cells could be cheaper than conventionally generated electricity.⁶⁴

The sun also drives the hydrological cycle of the earth and, in conjunction with other forces, creates the waves of the ocean, which possess tremendous energy. There are all kinds of devices for harnessing this marvelous energy but generally they do not work very well. In the United States, the most likely place for the use of wave-energy is the Pacific Northwest, where the Oregon and Washington coastlines enjoy the most consistent wave conditions. The drawbacks to harnessing the power of waves are technical, economic and environmental. The devices must be very large in order to be successfully moored. Oil rigs may serve as models, but it

seems likely that the costs of mooring wave-energy plants will prevent the business from becoming economic.⁶⁵

The power of falling water is an important source of industrial energy. Today hydroelectric plants supply a little under 4 percent of the overall energy use in the United States. Over the last few decades many of America's smaller hydro facilities were abandoned. Recently, however, a sharp reversal has occurred, and an entirely new trend in the direction of small hydro plants has developed. The opportunities of increasing US energy efficiency through expansion of small hydro facilities may yield a net result of supplying about 10 percent of the nation's electricity.⁶⁶

An enormous quantity of solar energy--estimated at 170 trillion kilowatts--is intercepted by our planet. When the energy strikes the upper atmosphere of the earth, the phenomenon called wind results. The wind has been used for centuries to propel sailing ships. Today there is renewed interest in developing wind-powered merchant vessels. On land, the winds have been a great source of motive power for the industrial revolution. Until the oil embargo, few large experiments in wind power were attempted. Today, a number of new techniques are being explored to exploit the power of the winds. Estimates of the potential for US energy production from wind turbines--which are basically propeller designs hooked up to a relatively simple turbine--are wondrous. Theoretically, the wind alone could produce the same amount of electricity in the United States as we produce today from all other sources. Put another way, two hundred thousand wind turbines of a 1 megawatt size could produce the equivalent of 9 million barrels of oil a day--more than we presently import.⁶⁷

Geothermal, earth heat, energy is one of our most plentiful resources. Experts estimate that 32 million quads (1 quad is a quadrillion BTUs) of energy are simmering within ten kilometers of the surface of the United

States. Some 2,300,000 acres of federal land have been leased for exploration and development, and in 1979 drilling increased 25 percent over 1978. The earth's heat can either be in the form of hot water or dry steam. The Department of Energy is seeking to extract heat from a third type of reservoir, hot dry rock. Such formations contain heat, but no water to bring it to the surface. Plans are to circulate water through drill holes connected by man-made fractures in the hot rock. Experts estimate that by the year 2020 geothermal could be adding 18.5 quads annually to the national energy pool.⁶⁸

E. Conservation: Conservation is no less an energy alternative than oil, gas, coal or nuclear. Indeed, in the near term, conservation could do more than any of the conventional sources to help the country deal with the energy problem it has. And contrary to the conventional wisdom, conservation can stimulate innovation, employment, and economic growth.⁶⁹

Wise and efficient use of energy resources in this country is a key element of our national response to the world energy situation. Net oil imports have been declining since 1979. A large part of the continuing decline came from prompt behavioral changes in energy use in response to the immediate price change, but another part was almost certainly a result of longer term trends toward more efficient use of energy and the removal of import subsidies.⁷⁰

The movement toward greater energy efficiency, toward greater tapping of conservation energy, will be governed by a complex interaction between government and society. A public policy is required that shapes strong coherent signals, all of which point in the same direction.⁷¹

The United States can use 30 or 40 percent less energy than it does, with virtually no penalty for the way Americans live--save that billions of dollars will be spared, save that the environment will be less strained,

the air less polluted, the dollar under less pressure, save that the growing and alarming dependence on OPEC oil will be reduced, and Western society will be less likely to suffer internal and international tension.

These are benefits Americans should be only too happy to accept.⁷²

The United States must develop a policy to wean itself from oil. An examination of the suppliers reveals that they are unreliable, unpredictable and radical. An increased dependence on imported oil means ever greater reliance on an unstable part of the world--the Middle East, and particularly Saudi Arabia. The events of the Iranian Revolution and its aftermath underscore for us that our oil supplies from the Middle East are not to be relied upon. The majority of our imported oil now comes from Mexico. Mexico also has some very serious problems which places its source of oil in jeopardy.

Mexican oil is quite unlikely to make any important change in the world oil picture. Mexican exports will be constrained by a ballooning domestic oil consumption brought on by a doubling of population by the end of the century--perhaps to over 125 million. Only a relatively small reserve base has yet been proven, and developing major new oil fields requires considerable time. Bureaucratic and political problems associated with the Mexican oil industry will further slow the development. Furthermore, the current official policy of Mexico is to limit exports to the pace required by domestic development rather than to the size of its oil reserves or the pressure of foreign demand. Mexican leaders want to hold a tight rein on development, because they are concerned that too much oil money too quickly will result in so much inflation that Mexico's other exports and its tourism will be priced out of world markets. Also, one should remember that even reserves of 100 billion barrels represent less than five years of the world's consumption.⁷³

The United States cannot place its national security in the hands of such instability. We must develop a phased program to divorce ourselves of petroleum. I visualize a multipronged program consisting of the following phases:

- I. Continued but declining reliance on imported oil as a portion of energy sources.
- II. Domestic oil and synthetic fuels as primary sources of energy. (Imported oil reduced to zero.)
- III. Solar and biomass as primary source of energy.
- IV. Assist allies through exporting technology and energy sources (coal, biomass) in the attainment of energy independence.
(This phase should be integrated throughout all phases to the extent possible and feasible, but initially emphasis should primarily be placed on an energy independent United States.)

This program must be implemented more rapidly than current references state. Current publications speak of these new energy sources coming into play during the period 2010 to 2025. We must move now and we have the capability to move significantly faster than that. I think that phase II above could be complete by 1990 and by the year 2000 we should be well into phase III.

How do we get our oil imports to zero? First, we continue our successful conservation program. We step up our technology for all alternative sources of energy particularly the development of synthetic fuels from coal, shale, biomass and nuclear. Solar must be used to the extent that current technology will allow. Alcohol must be mixed with petroleum for transportation in order to stretch it as far as we can. The development of mass transit systems must continue. Cable cars should replace buses. Development of the electric car, particularly for local driving must be

speeded up. As can be deduced from the above, electricity has to be our primary energy source. Electricity can be produced today from coal, nuclear, water, and solar.

Transportation amounts to a quarter of the national energy budget; of this, more than half is accounted for by people driving around in cars.⁷⁴ Major emphasis must be placed upon reduction of petroleum consumed for transportation. The efficiency of the internal combustion engine must continue to be improved. Technology exists for significantly more efficient engines than are in use today. Volkswagen has been working on a new vehicle that will get a fuel rating of 80 miles per gallon and Japanese car-makers are not far behind the Germans in the development of a 100 miles per gallon car.⁷⁵ These kinds of automobiles must get on the highways.

Domestic oil sources, coal and synthetic fuels are merely a bridge, a short term solution, to get us from petroleum to renewable sources such as solar and biomass. Solar and biomass are our long-term solutions. Sources of petroleum and coal will be exhausted someday. They are going to run out. We might as well take the step now to move to renewable energy sources. It is inevitable.

Our program must be multipronged because we cannot rely on any one source of energy nationwide. Energy sources must be used according to their prevalence. In those areas where geothermal is present it must be used; where water is present it must be used; where wood is available it must be used; where wind is prevalent it must be used. Solar has considerable promise across the entire country.

Community self-sufficiency becomes a distinct possibility for certain locales that possess the "correct" blend of renewable energy resources. Wind, or any single solar or renewable resource, taken alone, may not provide self-sufficiency; however, a hybrid combination of two or three

renewables does offer this possibility. A community must first identify its renewable energy resource potential, then consider scaling and compatibility of various renewable technologies, examine engineering feasibility, consider load management, costs, financing, institutional and legal factors and community access and acceptance. Wind energy used in conjunction with hydro, biomass, geothermal, and possibly solar photovoltaic offers some promise for community self-sufficiency.⁷⁶

Changing the energy base in our country will take time; it will be expensive for the federal and state government as well as the citizens. In the interest of national security, it is something we are all going to have to face no matter how unpleasant.

In a large and complex country, it need not be supposed that the transition from one energy base to another can be accomplished easily, quickly, or cheaply. Not everyone acknowledges the necessity for change: the "sunk costs" or capital investments at the individual and corporate levels in the older forms of energy and the devices it serves are enormous. And the financial costs, while staggering, are at least matched by political and social costs--some of which can be only inexactly measured.⁷⁷

The federal government has an important role to play in enhancing the security of the nation's fuel supply. Through a successful demonstration of synthetic fuel production, the United States could help to stabilize oil prices in the world market. Loans should be made to certain refineries for installing the new and sophisticated equipment required for processing heavy or high-sulfer petroleum. In the long-term, the United States must move toward use of electricity to replace oil and gas in every sector of the economy. The role of government is particularly important in cutting through much of the red tape that currently weakens the ability of electric utilities to construct and operate power plants. The licensing process for

nuclear power must be reformed to reduce opportunities for obstruction of operations and to ensure that once a plant is constructed it can be operated. To facilitate the greater use of coal, the federal government should move toward a cost-effective approach to environmental regulation. Finally the federal government may need to intervene in state and local regulation of utilities to ensure that the rate base reflects current economic conditions. Presently, rate structures vary considerably from state to state, leaving some utilities in worse financial straits than others. To ensure that the entire nation has adequate power supplies in the future, federal and state agencies must cooperate now to improve the economic stability of the electric power industry.⁷⁸

Federal and state governments have a key role to play through tax incentive and deductions for the installation of energy efficient, and alternative methods as well as conservation measures. These procedures must continue and be expanded for both individuals and industry.

The President must continue to exercise his legal authority to control oil imports through decontrolling oil and natural gas prices and establishing oil import fees. Decontrol of oil and even partial decontrol of natural gas will provide significant incentives to reduce oil-import demand and increase domestic production. More important, higher oil prices will provide a powerful incentive to reduce oil consumption. Another way to encourage more efficient use of the country's energy resources while weaning it from energy imports is to make imports more expensive than domestic supplies.⁷⁹

Raising prices of petroleum is a very sensitive area for the President to deal with as the public will consistently balk at higher prices. But, higher prices must be implemented and phased as the development of new energy sources is realized, controlled, and phased upon the country.

Increasing prices of petroleum must be handled very delicately as such action impacts significantly across the entire spectrum of the economy.

Adoption of such a program as has been outlined in this paper would sever the United States' dependence for energy resources from all other countries. The United States would be energy independent. This would free Middle East and Mexican oil for use by our allies. However, we should not leave our allies dependent upon these unreliable sources. We should share with them our technology and develop new technology jointly so that they can become energy independent.

Elimination of oil as an energy source would provide significant benefits for Americans as individuals and for this nation as a whole.

As a nation, America would gain a stronger dollar, improved balance of payments, security against disruption of energy supplies and a cleaner environment. As individuals, Americans would gain more goods and services, more secure jobs, less inflation and higher wages and salaries.⁸⁰

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